A New Stereo Matching Method Based on Sub-pixel Corner Detection

Dou Zhao *, Ding Liu, Yanxi Yang
School of Automation and Information Engineering,
Xi'an University of Technology, 710048
***Email:douzhaodou@126.com**

Abstract

Corner detection and stereo matching play an important role in the machine vision. The detection accuracy and matching velocity are highly demanded in the stereo vision. In this paper, dual-harris corner detection algorithm and corner matching method are proposed. Corner detection algorithm adopts random mid-point displacement method in fractal geometry to subdivide and amplify the pixel precision corner detected by the harris algorithm and its surrounding pixel block. And then, it reuses harris algorithm to provide sub-pixel corner position by detecting the fractal interpolation map and the FBS surface. This method accords with human thought manner that is to observe things ranging from whole to part and form macroscopy to microcosm, which avoids detecting the edge and fitting lines by comparing with the common sub-pixel detection algorithm. Corner matching method uses the corner characteristic constraint to limit the amount of the alternative corners in the searching window, which sharply decreases the amount of correlation coefficient computation, and saves the stereo matching time. Simultaneity, the constraint of disparity gradient is selectively adopted to increase the stereo matching veracity. Large numbers of experiment results show the veracity and real-time of the proposed method.

keywords: fractal geometry; sub-pixel; corner detection; corner characteristic; gray correlation; gradient of disparity; stereo matching

1. Introduction

Positioning and matching of feature points are the foundation of binocular stereovision, 3D reconstruction and tracking. The positioning accuracy and the matching velocity strongly affect the calibration precision of the camera; furthermore affect the precision and the velocity of the measurement and reconstruction.

Corner served as the most used feature points plays an important role in the machine vision[1,2]. Developing with the need of high accuracy image measurement system, sub-pixel subdivided technology is noticed by the project technology researchers[3,4]. Generally, for sub-pixel corner positioning, pixel precision positioning and sub-pixel positioning must be done[1]. For pixel precision, numbers of integral pixel precision positioning methods are proposed, such as, harris and susan algorithms[5], which are widely applied owing to their fast operation velocity, high precision and non-sensitivity of the noise. For sub-pixel precision, according to detecting the sub-pixel edge of the image and fitting the polygonal figuration of the target, the point of intersection of two (or more) lines[6] is regarded as the accurate corner position. Hough transform method and the method of linear fitting with the detected edge are used to seek for the edge lines. While large numbers of lines exist in the image, the amount of computation for Hough transform is tremendous, and the number of intersection point is large for abundant lines, the true or false corners should be recognized[1]. So, Hough transform is unsuitable for the sub-pixel corner positioning. In this paper, in order to get the feature points positioning with a high precision, dual-harris corner detection algorithm based on fractal interpolation is proposed.

When getting corner position, stereo matching should be considered, which is the developing direction and the research focus in the field of computer vision, and has widely applied prospect and potential economic value[7,8]. Up to now, three methods are used for stereo matching[9]. Area-based matching method can provide a high precision, but choosing the matching window size is difficult, the amount of computation is tremendous and the velocity is slow. The advantage of feature-based matching method is robust anti-interference and quick velocity, but feature extraction and the positioning process directly influence the matching precision. Phase-based matching method can inhibit the high frequency noise and be suitable for parallel processing, but solving the problem of phase singularity and phase wrap is difficult. In this paper, we propose a corner matching method based on the corner characteristic and gray correlation to improve the matching velocity.

978-0-7695-3336-0/08 $25.00 © 2008 IEEE
DOI 10.1109/CSSE.2008.316

2. Dual-harris corner detection algorithm

The pixel gray distributing of the image obtained from nature has fractal character. Simultaneity, the gray changing of the image edge area can reflect its basic shape and has randomicity to a certain degree. So the gray of this image area obeys to the FBM law, which is the important part of the fractal geometry[10]. The FBM and FBS are detailed in reference 11; the existence of condition process is proved and the fractal interpolation method is also provided.

To improve the common sub-pixel detection algorithm and combine the thinking characteristics of the fractal geometry, dual-harris corner detection algorithm based on fractal interpolation is proposed in this paper. It accords with human thinking manner to observe the things by extracting the interested part, and then subdividing and amplifying it carefully. Firstly, the pixel precision corners are positioned by adopting the harris corner detection algorithm. Harris algorithm[12] is the classical corner detection algorithm because of its simple operation, strong adaptability and stabilization. Secondly, the area pixels surrounding the detected corner are selected to produce the FBS surface via the random mid-point displacement method[10]. These interpolated surfaces are regarded as the sub-pixel precision surfaces corresponding with the detected pixel corners, and also are regarded as the subdivision and amplification of the source pixel corners. Finally, the sub-pixel corners are detected from the FBM surfaces by reusing the harris algorithm.

The steps of the proposed method for detecting corners are as follows:

Step1: Adopt fundamental image preprocessing, such as graying and filtering out some noise, to the source stereo images so as to provide gray images with less noise, which are easy to process.

Step2: Detect corners from the preprocessed images via harris algorithm, actually the corner is detected by computing the first-order curvature of a matrix which correlates to the autocorrelation function of the image.

Step3: Every image block with the size of $n \times n$, is composed of area pixels surrounding with every detect corners obtained in step 2, which is served as source image. So, fractal interpolation map and the FBS surface corresponding with every image block, which are regarded as the sub-pixel image block, can be obtained via the random mid-point displacement method in fractal geometry.

Step4: Detecting the corner from the sub-pixel image block by reusing the harris algorithm to obtain the sub-pixel corner position.

3. Fast corner matching method

In corner matching method, gray correlation matching based on gray correlation hypothesis is commonly used. Given knowning a and unknowning b, it can be simply narrated as follows:

Firstly, searching window can be obtained by selecting image block from the right image. Secondly, according to the given size of the image correlation window, all of the gray correlation coefficient between corner a and every corner contained in searching window can be acquired. Finally, the corner b can be obtained by comparing gray correlation coefficient with the threshold.

It is easy to know that the amount of computation for correlation coefficient is tremendous and time-wasted if there are numbers of corners contained in searching window. Commonly, two methods are showed to solve this problem. One is to decrease the corner number, which can enhance the matching velocity. However, it may take out the real matching point if the number of the alternative corners is directly restricted, and the optimization matching will not be obtained. The other one is to predigest the formula of normalizing correlation coefficients or to prestore the mean and variance of the matching image block, which is needed to compute time and again. But, saving time resource will cost the memory resource.

Corner matching method based on the corner characteristic is proposed in this paper, and it uses the grads similarity constraint of the corner and its surrounding pixels. The value R of the corner characteristic response function[12] obtained by harris algorithm for corner detection, as the notable characteristic of the corners, is used to depict the corner grads. We suppose that the corner eigenvalue is contiguous and semblable, which means that the ratio between a couple of matching corners falls in a threshold range. Limiting cases of this suppose is that the ratio should be close to 1 if the couple of the stereo matching images are uninfluenced by illumination and noise. Because illumination changing and noise influence are inevitable in practice, we obtain the threshold of the ratio about ranging from 0.2 to 2 by observing the matched corner eigenvalue in experiment. Figure 1 shows the corner characteristic ratio histogram between one corner selected randomly from the left image of the House stereo images and all of the corners from the right image, the corners fallen into the threshold range is only about 39.39%.

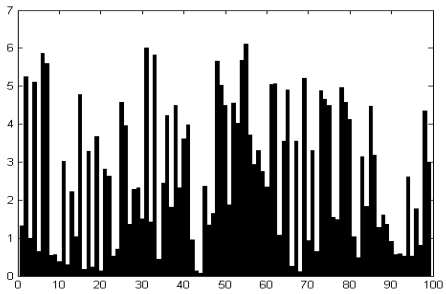

Figure 1. Ratio histogram of the corner characteristic

According to the corner characteristic constraint, the number of the alternative corners is sharply decreased, so the amount of computation for correlation coefficient is decreased and the stereo matching time is also saved. The normalizing correlation coefficient in reference 5 is adopted to compute the gray correlation in this paper.

Mistaken matching points and the one-to-many matching are regarded to be inevitable via the gray correlation matching method. The constraint of disparity gradient in reference 5 is adopted. Numbers of the corners can be detected by harris algorithm, however, it is meaningless to find every couple of corners corresponding with each other. In reference 13, only 8 couples of matching corners are needed to solve the fundamental matrix by the 8-eight algorithms. In a word, it is not anxious to execute the step of disparity gradient if the matching result has obtained via the method based on corner characteristic and gray correlation, and the number of matching corners should be judged at first; namely, the aforementioned result is the last matching result if the number of the matching corners satisfies the needed number; otherwise, the constraint of disparity gradient is used to increase the matching corners by selecting the true corner form the alternative corners.

Figure 2 shows the flow chart of the stereo matching method.

4. Experiment results

The experiment is run in the matlab6.5 software on the Pentium(R)4 PC with 2.60GHz(CPU). We use the House stereo matching images to test, which is interpolated 5 times with the fractal parameter h=0.25; α=0.1. Gray correlation window is 3×3; image searching window is 1/8 width×1/8 height of source image, and the threshold range of corner characteristic values is [0.5,2], and the threshold of correlation coefficient is 0.8. The results are showed in figure 3; sign + is the position of the corner and the number is its sequence number. Only some results of the detected corners are showed here and some matching results of the stereo matching are showed in table 1. Then, we compare the disparity gradient matching method based on gray correlation (called method 1) with the proposed method (called method 2). The results are showed in table 2, and it is concluded that the proposed method can provide a fast and exact matching result.

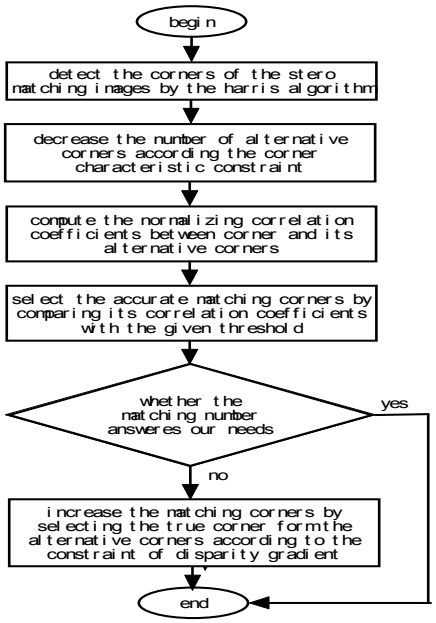

Figure 2. Flow chart of the stereo matching

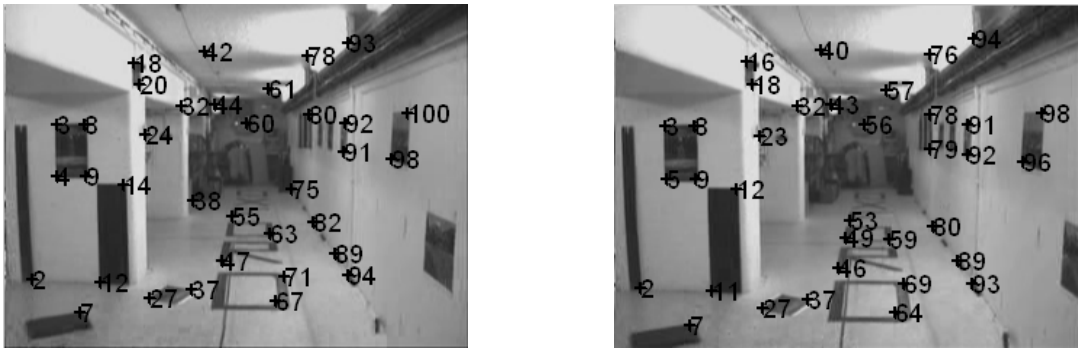

Figure 3. House stereo matching images

Table 1. The matching result with the pixel and sub-pixel precision of House stereo matching images

Left image in House stereo matching images					Right image in House stereo matching images				
Corner number	Pixel X	Sub-pixel X	Pixel Y	Sub-pixel Y	Corner number	Pixel X	Sub-pixel X	Pixel Y	Sub-pixel Y
2	193	193.030	20	20.031	2	198	198.030	19	19.031
4	121	121.350	37	37.354	5	122	122.040	37	37.039
7	216	215.700	53	52.698	7	224	224.020	53	53.023
12	195	195.350	67	67.354	11	200	200.350	68	68.354
14	127	126.060	83	82.063	12	129	128.710	85	84.708
24	92	91.719	98	97.719	23	92	92.039	101	101.040
32	72	72.023	123	123.020	32	71	71.031	127	127.030
44	71	71.039	146	146.040	43	70	70.031	150	150.030
93	28	28.039	238	238.040	94	24	23.719	248	247.720
100	77	77.031	279	279.030	98	76	76.023	295	295.020

Table 2. The compared results of the matching method

matching images	Matching methods	Image size	Corner number		Matching number	Matching time(s)	Mismatching rate
House	Method 1	320×240	left	right	90	0.7340	5.56%
	Method 2		103	99	74	0.0940	6.76%

5. Conclusions

Dual-harris corner detection algorithm based on fractal interpolation is proposed in this paper. The harris algorithm is used to obtain the corners position of pixel precision; the random mid-point displacement method is used to obtain sub-pixel surface by the fractal interpolation method; and the sub-pixel precision corners are obtained by reusing the harris algorithm. For stereo matching, corner matching method based on the corner characteristic and gray correlation is also proposed. The constraint of corner characteristic is used to decrease the number of the alternative corners; the normalizing correlation coefficient is used to obtain stereo matching; and the constraint of disparity gradient is selectively used to increase the number of the matching corners if it is insufficient. The simulation results show the validity of the methods in this paper.

References

[1] Liu Tao, Chen Guozhu, Li Yuanzong. Using Subpixel Corner Detection to Improve Calibration Precision[J]. Mechanical Engineering & Automation, 2007,(4):28-30.

[2] Z Zhang. A flexible new technique for camera calibration. IEEE Transactions on Pattern Analysis and Machine Intelligence. 2000, 22(11) :1330-1334 .

[3] Fu Peng, Gao Xiaorong. Contrast Study of Sub-pixel Edge Detection Based on Moment[J]. Microcomputer Information,2007,23(6-3):264-265.

[4] Lyvers E P, Mitchell O R. Subpixel measurements using a moment-based edge operator . IEEE Transactions on Pattern Analysis and Machine Intelligence, 1989, 11(12) :1293-1309 .

[5] Zhu Songli, Dai Lirong, Song Yan, Wang Renhua. Corners Matching Method Based on Corner's Threshold and Gradient of Disparity Constraint[J]. Computer Engineering and Applications, 2005,(34): 62-64.

[6] Kong Dan, Li jiegu. Image Matching Technique with Sub-pixel Precision[J].Infrared and Laser Engineering, 1998,27(1):29-32.

[7] Chen Panjun, Qi Feihu. A New Feature-point-based Stereo Matching Algorithm[J].Journal of Image and Graphics,2005,10(11):1411-1414.

[8] Bhat D N,-Nayar S K. Ordinal Measures for Image Correspondence. IEEE Trans. Pattern Analysis and Machine Intelligence. 1998, 20 :415-423 .

[9] Zhang Yanfeng. 3D Reconstruction of Anomalistic Objects Based on Stereo Vision[D]. Dalian University Of Technology,2005.

[10] Jin Hao, Jiang Wenhua, Yu Xinrui, Wang Shigang. Subpixel interpolation method based on different regions[J]. Optical Instruments, 2003,25(4): 7-11.

[11] Kenneth Falconer, Zeng Wenqu. Fractal Geometry: Mathematical Foundations and Applica-tions [M]. Posts & Telecom Press,2007.

[12] Wang Sheyang. Research on Several Problems of Robot Visual Servoing System[D].Harbin Institute of Technology,2006.

[13] Hartley,R.I. In defence of the 8-eight algorithms [A]. In 5th International Conference on Computer Vision [C]. MIT: IEEE,1995.